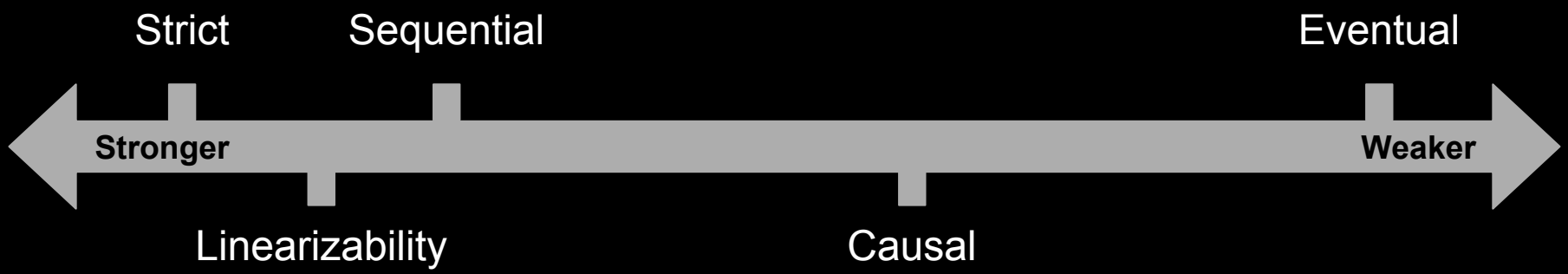
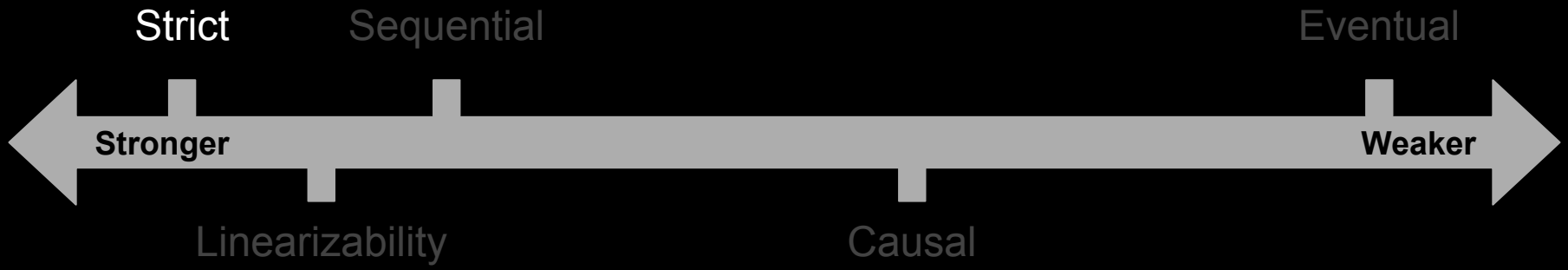
Consistency

11/17/2017

Consistency Models



Consistency Models



Strict Consistency

- Instantaneous writes: All writes immediately observed by all processes
- Global clock: Order ops across all processes as if on one machine
- Strongest consistency

Pros: Easily reason about correctness

Cons: Highly unavailable

Strict Consistency Example

Strict? **Yes**

P1: W(x)b

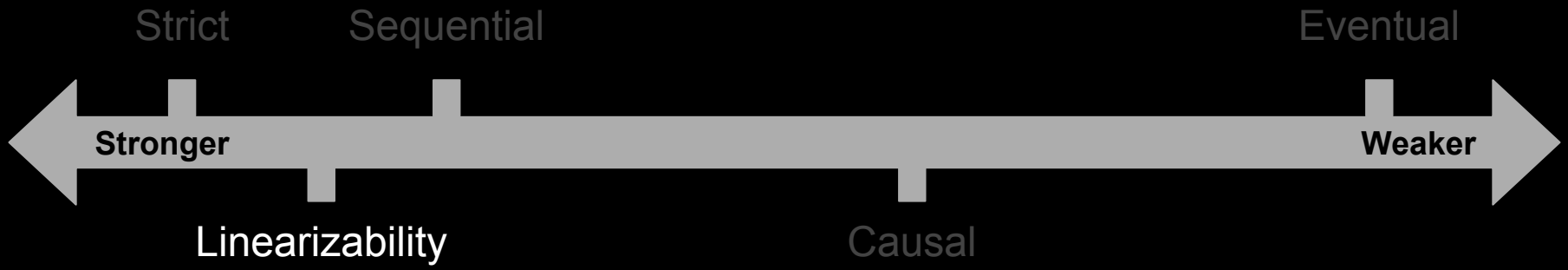
P2: R(x)b R(x)b

Strict? **No**

P1: W(x)b

P2: R(x)a R(x)b

Consistency Models



Linearizability

- Total order: All processes agree on the same sequence of ops
- Global clock: Determine sequence of ops using real time
- Difference from *strict consistency*?
  - Writes don't have to be *immediately* observed by everyone
- Properties
  - A completed write appears to all future reads
  - Once a read sees a value, all future reads must also return the same value (until new write)

Pros: Easily reason about correctness

Cons: High read and write latencies

Linearizability Example

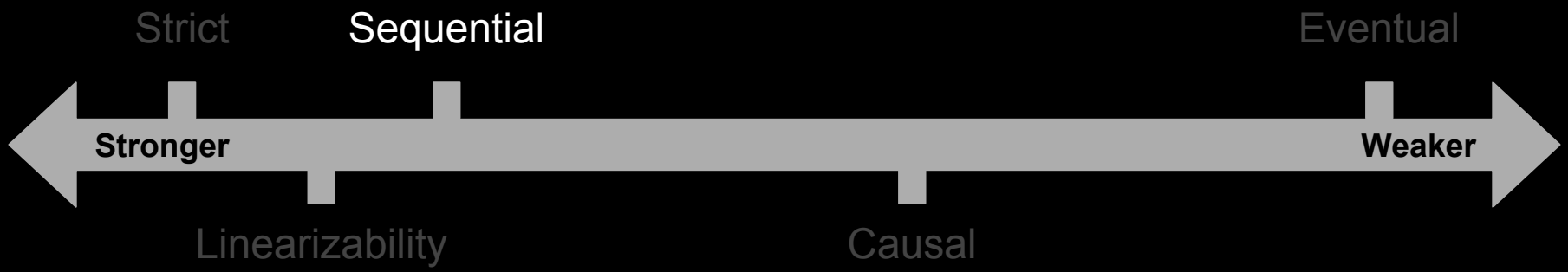
Linearizable? **Yes**

P1:	W(x)a			
P2:		W(x)b		
P3:			R(x)a	R(x)b
P4:			R(x)a	R(x)b

Linearizable? **No**

P1:	W(x)a			
P2:		W(x)b		
P3:			R(x)b	R(x)a
P4:			R(x)b	R(x)a

Consistency Models



Sequential Consistency

- Total order: All processes agree on the same sequence of ops
- Difference from *linearizability*?
  - Sequence of ops not determined by global clock

Pros: Easily reason about correctness, more permissive

Cons: Many possible sequential executions, non-deterministic

Sequential Consistency Example

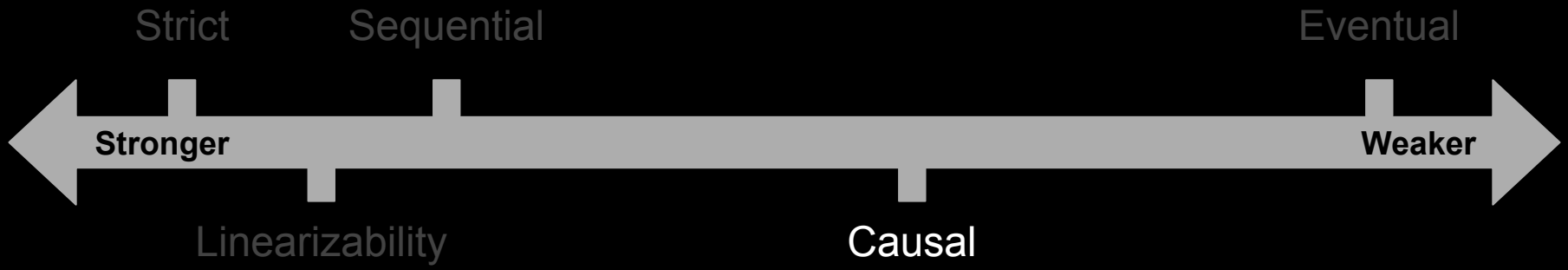
Sequentially Consistent? **Yes**

P1:	W(x)a			
P2:		W(x)b		
P3:			R(x)b	R(x)a
P4:			R(x)b	R(x)a

Sequentially Consistent? **No**

P1:	W(x)a			
P2:		W(x)b		
P3:			R(x)b	R(x)a
P4:			R(x)a	R(x)b

Consistency Models



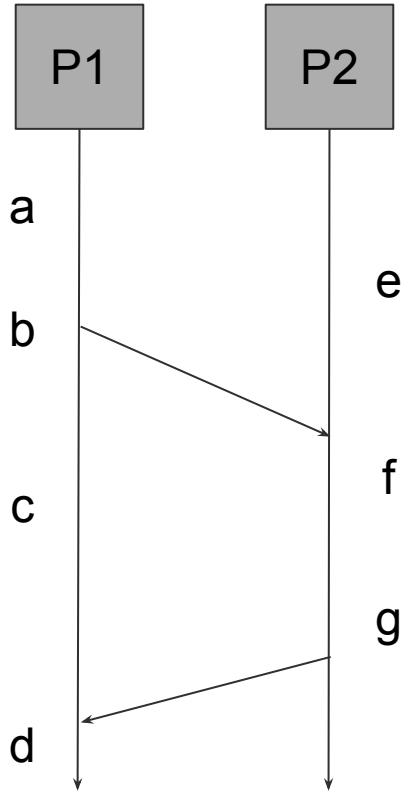
Causal Consistency

- Partial order: Order causally related ops the same way across all processes
- Difference from *sequential consistency*?
  - Only casually related ops need to be ordered
  - Concurrent ops may be ordered differently across different processes

Pros: Preserves causality while improving efficiency

Cons: Need to reason about concurrency

Ops	Concurrent
a,b	**No**
a,e	**Yes**
a,g	**No**
c,e	**Yes**
c,d	**No**
d,g	**No**
d,f	**No**
e,g	**No**
a,d	**No**



Causal Consistency Example

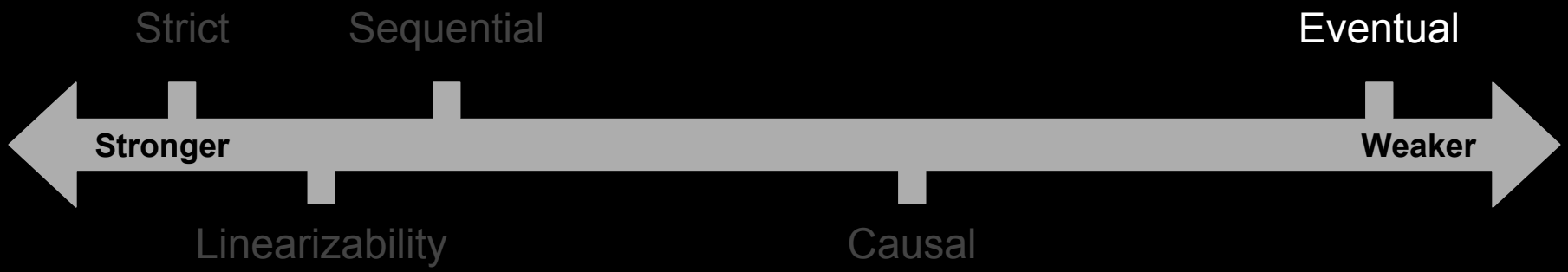
Causally Consistent? Yes

P1:	W(x)a			
P2:		W(x)b		
P3:			R(x)b	R(x)a
P4:			R(x)a	R(x)b

Causally Consistent? No

P1:	W(x)a				
P2:		R(x)a	W(x)b		
P3:				R(x)b	R(x)a
P4:				R(x)a	R(x)b

Consistency Models



Eventual Consistency

- Eventual convergence: If no more writes, all replicas *eventually* agree
- Difference from *causal consistency*?
  - Does not preserve causal relationships
- Frequently used with application conflict resolution, anti-entropy

Pros: Super duper highly available

Cons: No safety guarantees, need conflict resolution

In a nutshell...

Strict consistency: all writes are immediately observed

Linearizability: Total order + real time guarantees

Sequential consistency: Total order

Causal consistency: Partial order that respects causal relationships

Eventual consistency: Eventually everyone should agree on state

Exercise 1:

P1:	W(x) 1			R(y) 4
P2:		R(x) 1		R(y) 4
P3:		R(x) 1	W(y) 4	
P4:		R(x) 1		R(y) 4

Consistency Model:

Strict	**Yes**
Linearizable	**Yes**
Sequential	**Yes**
Causal	**Yes**
Eventual	**Yes**

Exercise 2:

P1:	W(x) 3				W(y) 7	
P2:		W(x) 1				
P3:			R(x) 1	R(x) 3		R(y) 7
P4:			R(x) 1	R(x) 3		R(y) 7
P5:			R(x) 1	R(x) 3		R(y) 7

Consistency Model:

Strict	**No**
Linearizable	**No**
Sequential	**Yes**
Causal	**Yes**
Eventual	**Yes**

Exercise 3:

P1:	W(x) 3				W(y) 7	
P2:		W(x) 1				
P3:			R(x) 1	R(x) 3		R(y) 7
P4:			R(x) 3	R(x) 1		R(y) 7
P5:			R(x) 1	R(x) 3		R(y) 7

Consistency Model:

Strict	**No**
Linearizable	**No**
Sequential	**No**
Causal	**Yes**
Eventual	**No**

Exercise 4:

P1:	W(x) 1					
P2:		W(x) 3				
P3:			W(x) 7			
P4:				R(x) 3	R(x) 7	R(x) 1
P5:				R(x) 3	R(x) 1	R(x) 7

Consistency Model:

Strict	No
Linearizable	No
Sequential	No
Causal	Yes
Eventual	No

Exercise 5:

P1:	W(x) 1						
P2:		W(x) 3					
P3:			R(x) 3	W(x) 7			
P4:					R(x) 3	R(x) 7	R(x) 1
P5:					R(x) 3	R(x) 1	R(x) 7

Consistency Model:

Strict	**No**
Linearizable	**No**
Sequential	**No**
Causal	**Yes**
Eventual	**No**

Exercise 6:

Consistency Model:

Strict	**No**
Linearizable	**No**
Sequential	**No**
Causal	**No**
Eventual	**No**

P1: W(x) 1

P2: R(x) 1 W(x) 3

P3: R(x) 3 W(x) 7

P4: R(x) 3 R(x) 7 R(x) 1

P5: R(x) 3 R(x) 1 R(x) 7